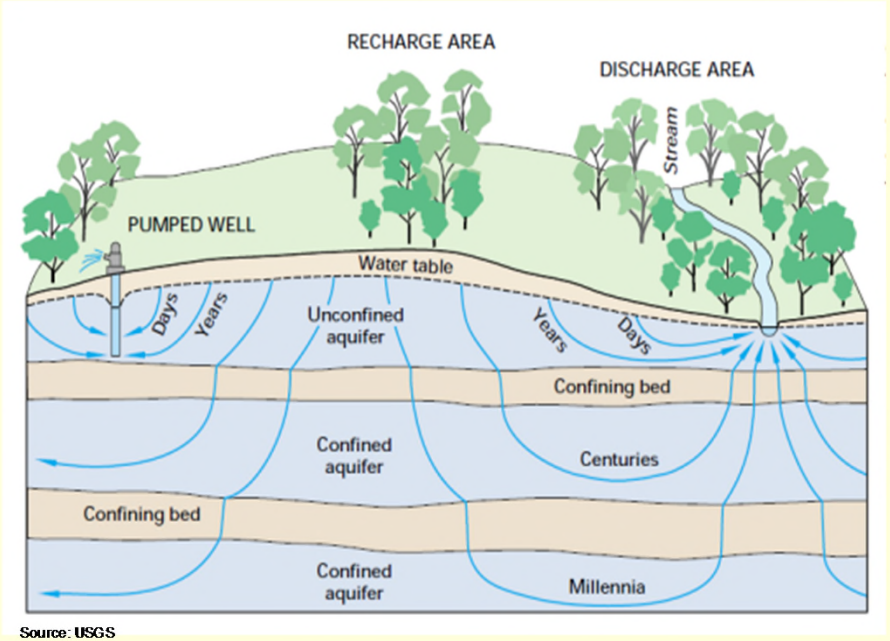
Chloride Trends in Ohio Public Water System Wells

Working Together for Clean Water
9TH NATIONAL MONITORING CONFERENCE ■ April 28 – May 2, 2014 ■ Cincinnati, Ohio
NWQMC



Source: USGS

Mike Slattery

Ohio Environmental Protection Agency
Division of Drinking and Ground Waters

OhioEPA

Acknowledgments

Ohio EPA District Staff

Ohio EPA district staff plan and collect all Ambient GW Program data.

Ohio EPA Central Office Staff

Chris Kenah, Linda Slattery, Jeff Patzke

Division of Environmental Services

Have provided inorganic and organic analyses for life of program

Outline

- Chloride ion data
- Approach / Results
- Trend Tests
- Individual system examples
- Statewide perspective
- Conclusions

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Chloride Data

- Ohio's Ambient Ground Water Quality Monitoring Network
  - raw water monitoring program
  - 193 wells analyzed; 1941 to present
  - 2004 Cl slope comparison: 131/193 wells
- Why Chloride?
  - Conservative; can infer pathways

Natural	Anthropogenic
brines	sewage
precipitation	livestock
halite /other salts	water conditioning salt
silicates, phosphates	fertilizers
seawater	Industrial
	road salt

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Approach

- Intra-well time series generated for all 193 wells
  - Chloride concentration vs sample date
    - Reporting limit of 5 mg/L inserted where necessary, no impact
  - No removal of duplicates, outliers
  - Environmental data are messy:
    - Either 6 month or 18 month sample intervals
    - PWS time series are not smooth, only partially monotonic
    - Because wells are pumping, operational influence is part of signal

- Trend tests run on each system
  - Table built to contain all statistics
  - Slopes analyzed by various graphical/statistical methods

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Trend Tests

- Document water quality changes over time
  - Due to random variation ?
  - Or statistically significant ?

- Robust Linear Regression
  - Tends to slighlty overestimate relative to Sen's
  - More sensitive to large changes/outliers

- Mann Kendall and Sen's Slope
  - Nonparameteric statistics
  - Seasonality and Autocorrelation are not issues
  - Estimates:
    - Significance of trend – Mann Kendall's Z & p-value of Sen's
    - Magnitude of trend – slopes
    - Slopes are in units of mg/L/year

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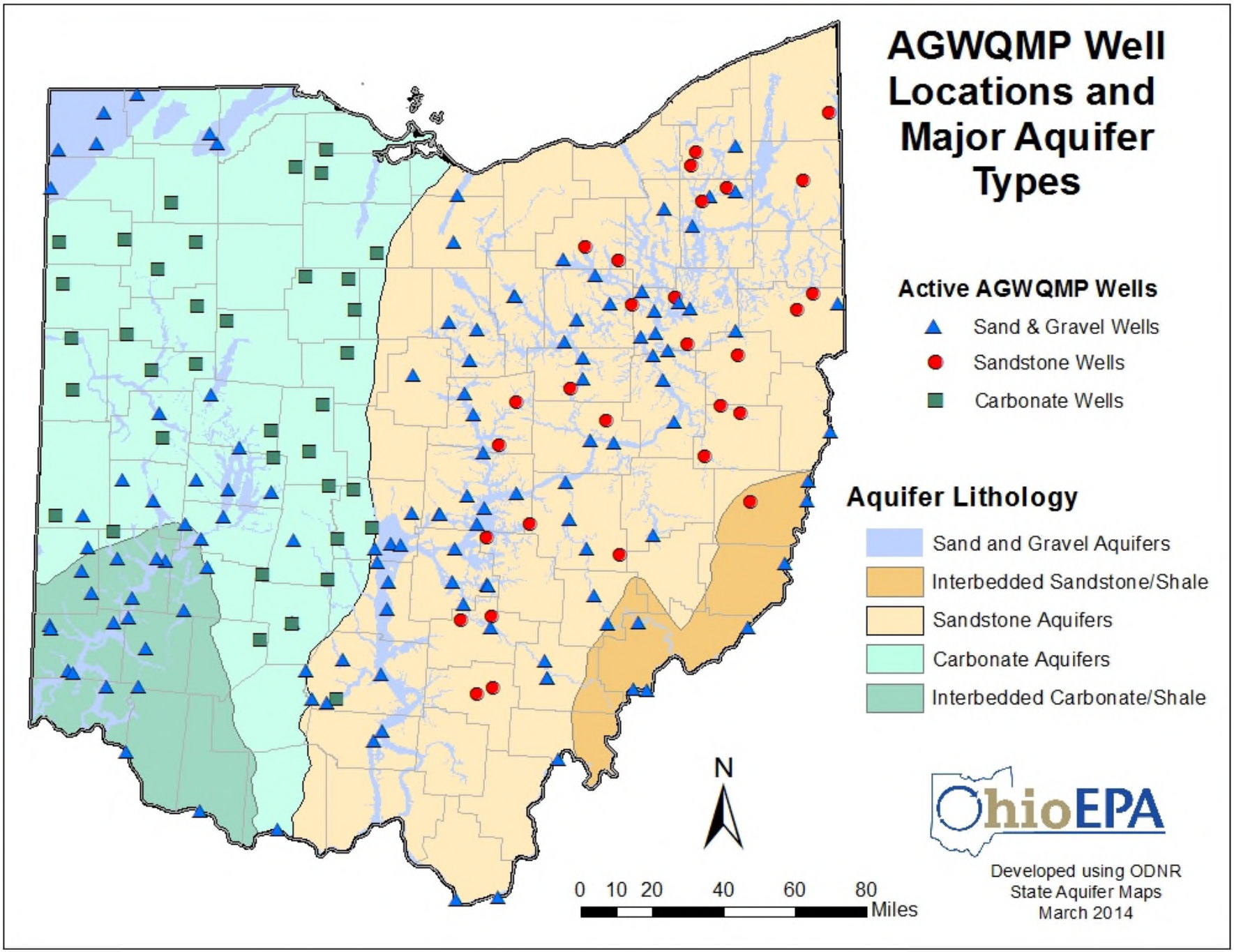
AGWQMP Well Locations and Major Aquifer Types
Active AGWQMP Wells
Sand & Gravel Wells
Sandstone Wells
Carbonate Wells
Aquifer Lithology
Sand and Gravel Aquifers
Interbedded Sandstone/Shale
Sandstone Aquifers
Carbonate Aquifers
Interbedded Carbonate/Shale
N
0 10 20 40 60 80
Miles
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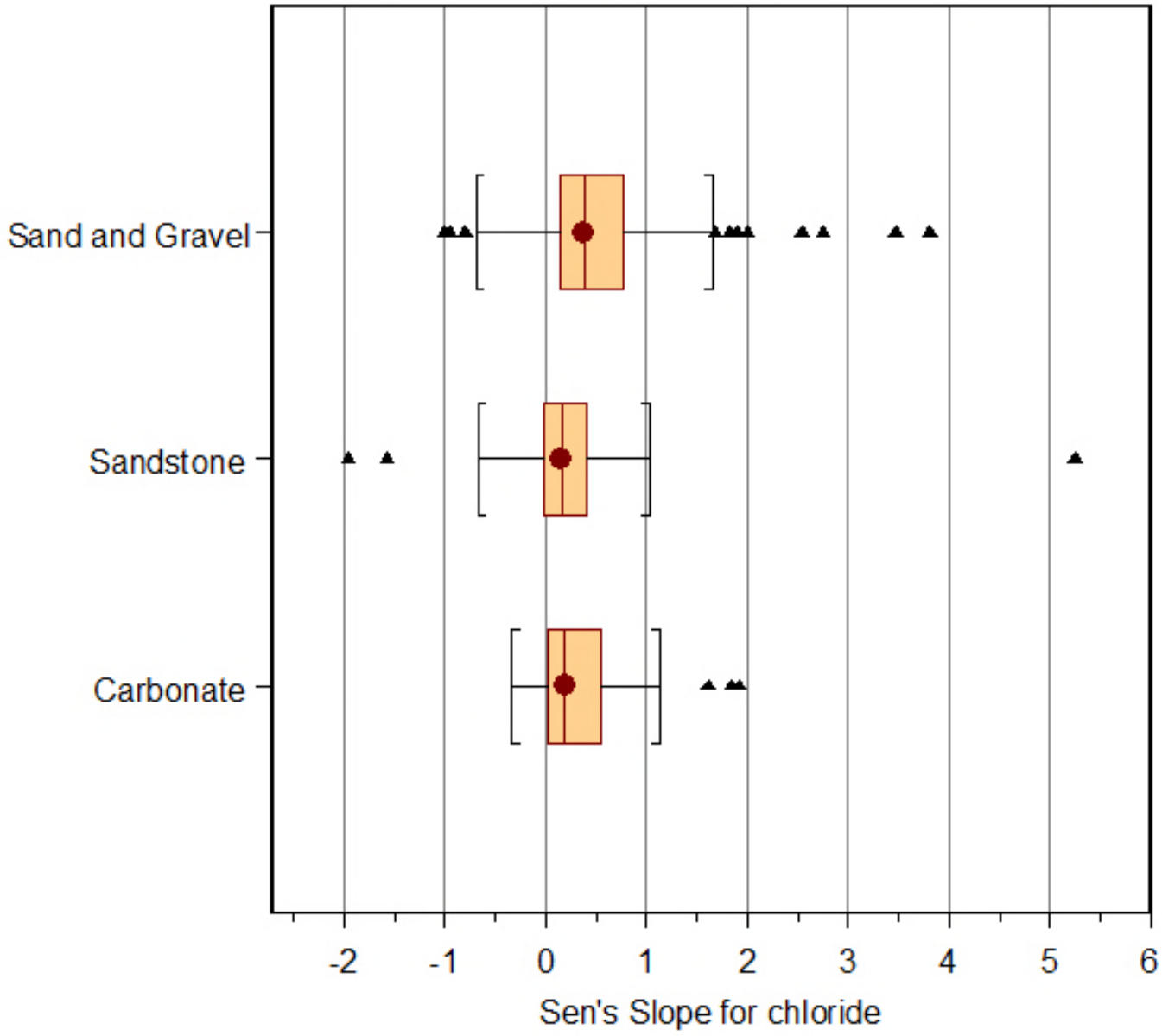
Developed using ODNR State Aquifer Maps March 2014

Sen's Slope for chloride by Major Aquifer Type



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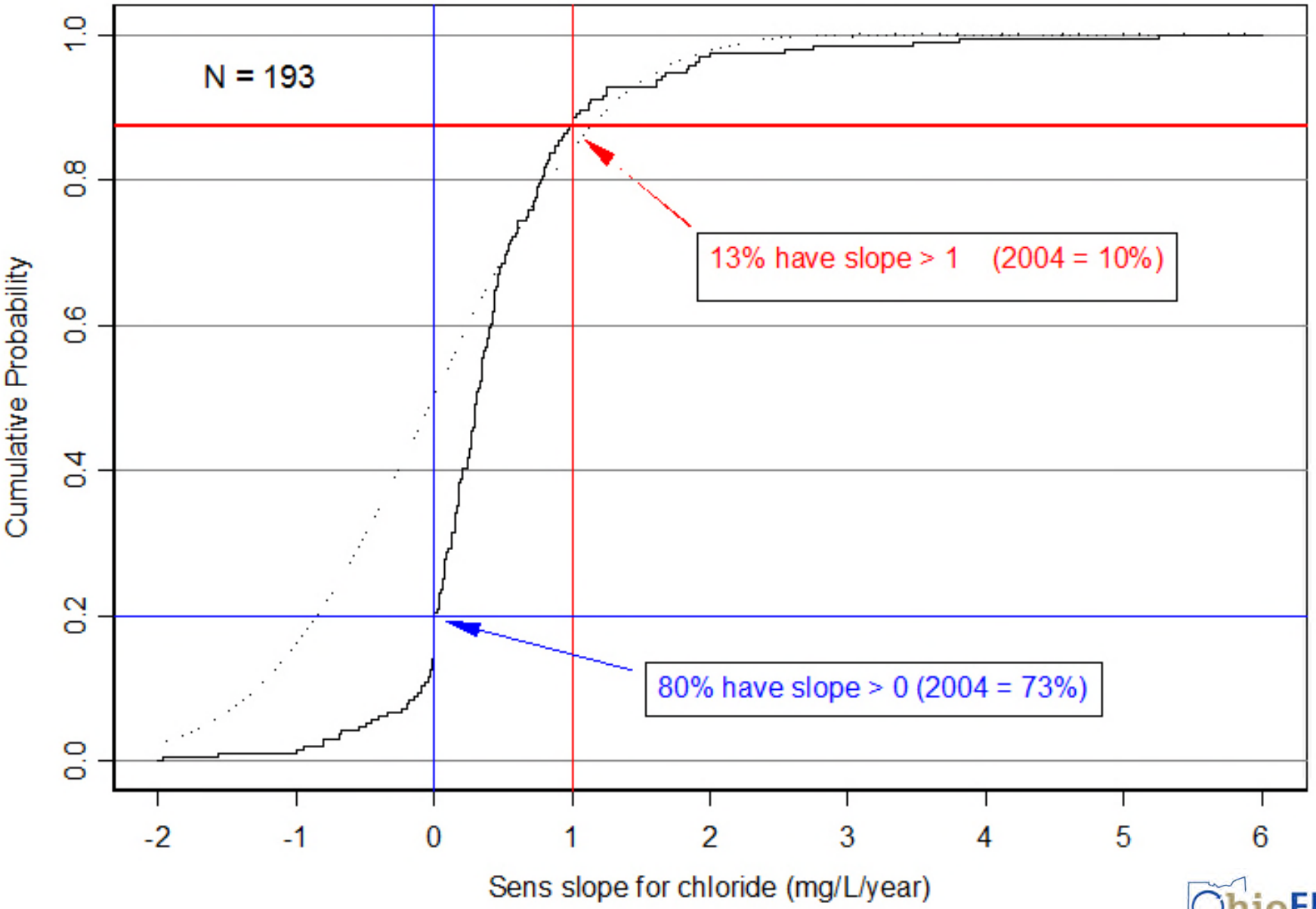
Sen's Slope for chloride: Empirical and Normal CDFs



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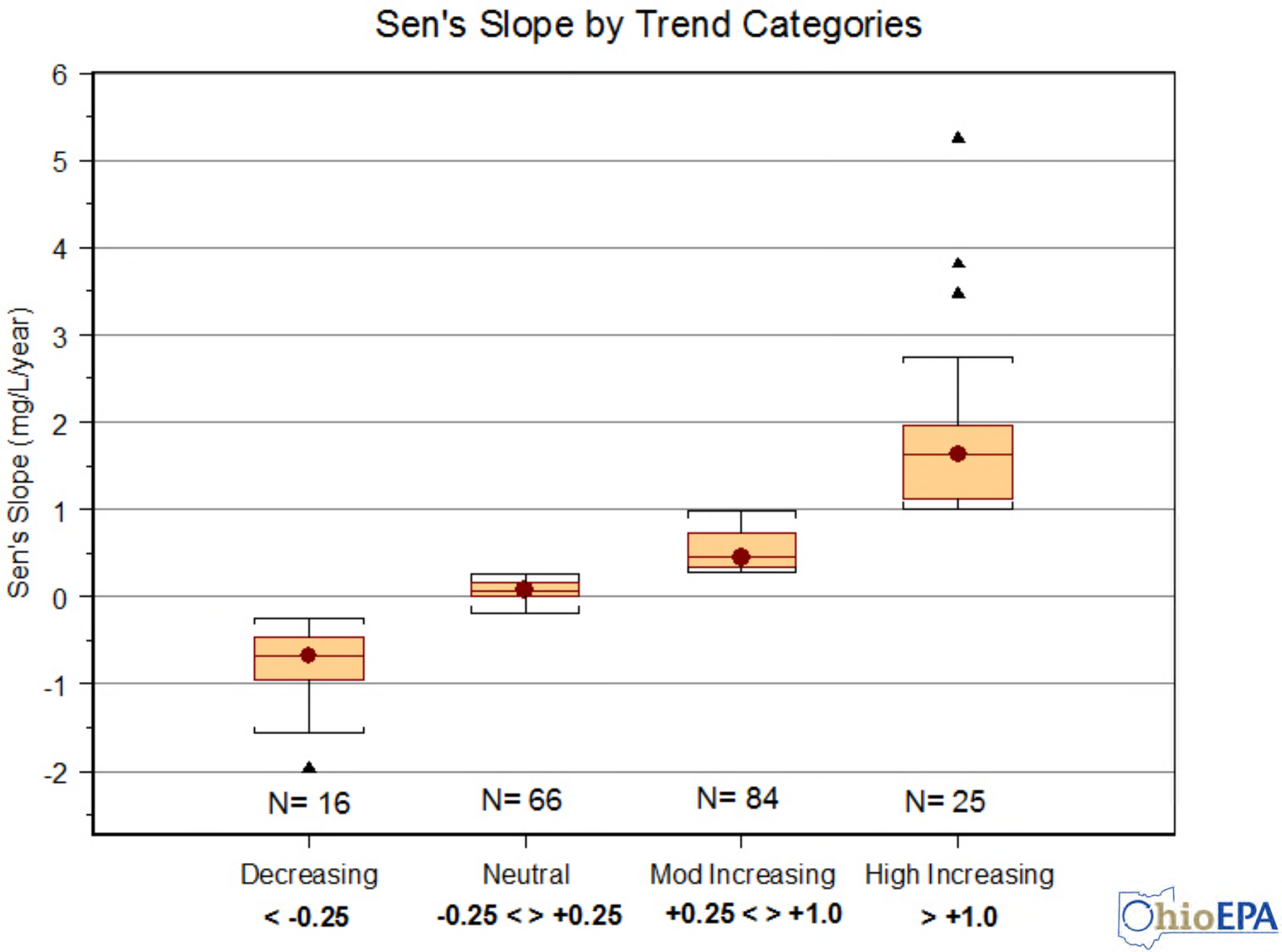
Sen's Slope by Trend Categories
Sen's Slope (mg/L/year)
6
5
4
3
2
1
0
-1
-2
N= 16
N= 66
N= 84
N= 25
Decreasing
< -0.25
Neutral
-0.25 < > +0.25
Mod Increasing
+0.25 < > +1.0
High Increasing
> +1.0
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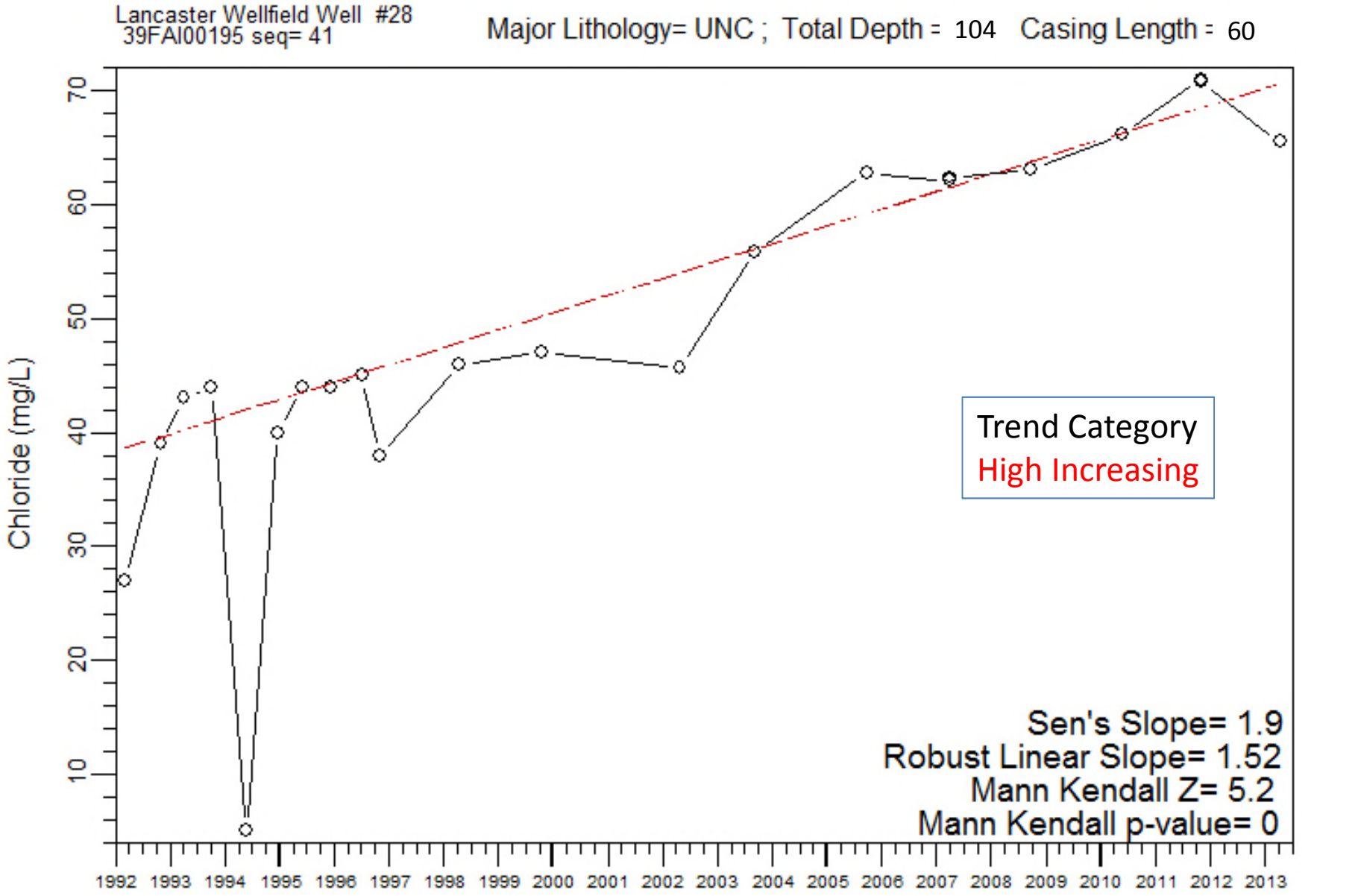
Lancaster Wellfield Well #28
39FAI00195 seq= 41
Major Lithology= UNC ; Total Depth = 104 Casing Length = 60
Chloride (mg/L)
10
20
30
40
50
60
70
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Trend Category
High Increasing
Sen's Slope= 1.9
Robust Linear Slope= 1.52
Mann Kendall Z= 5.2
Mann Kendall p-value= 0

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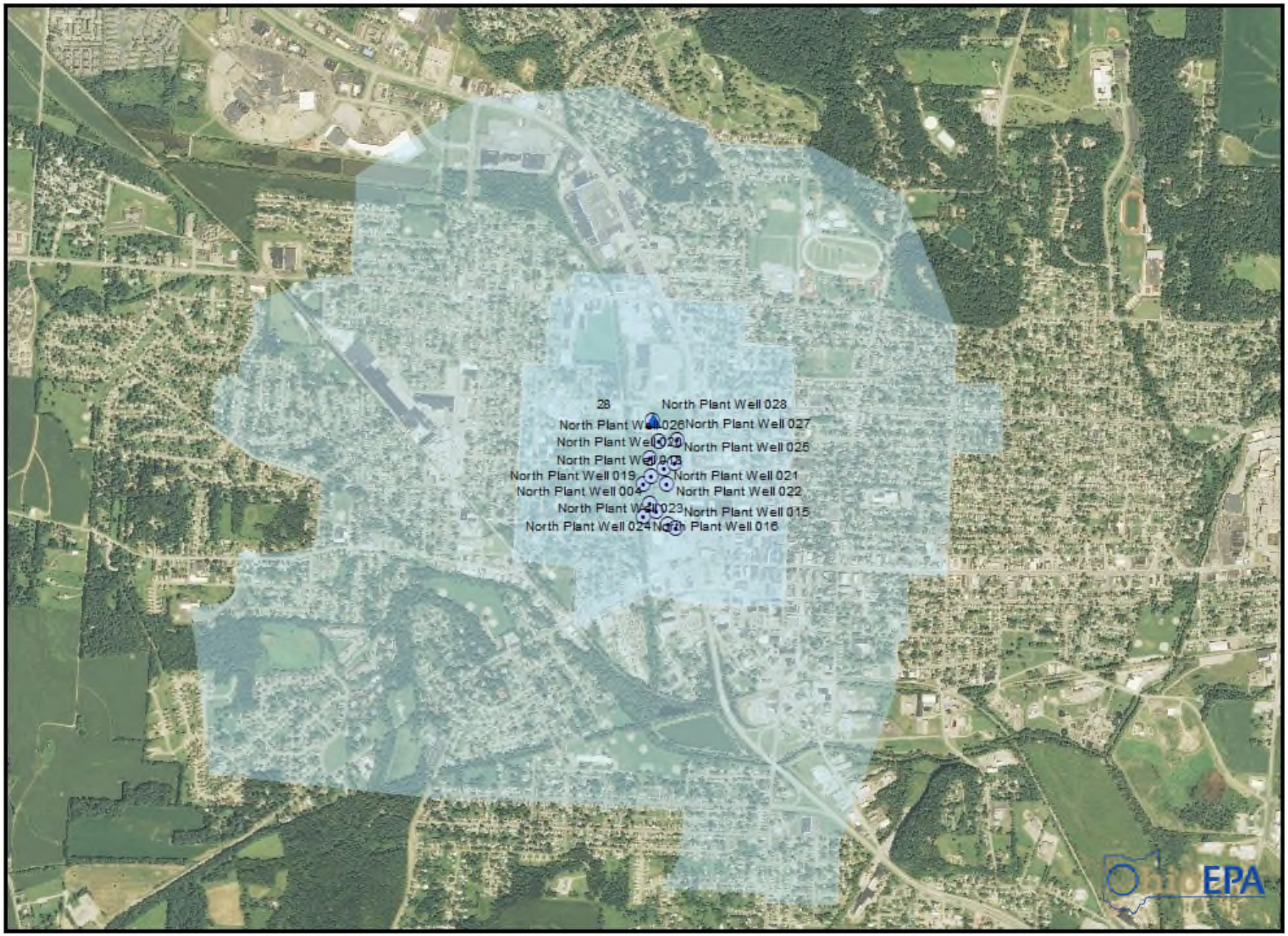
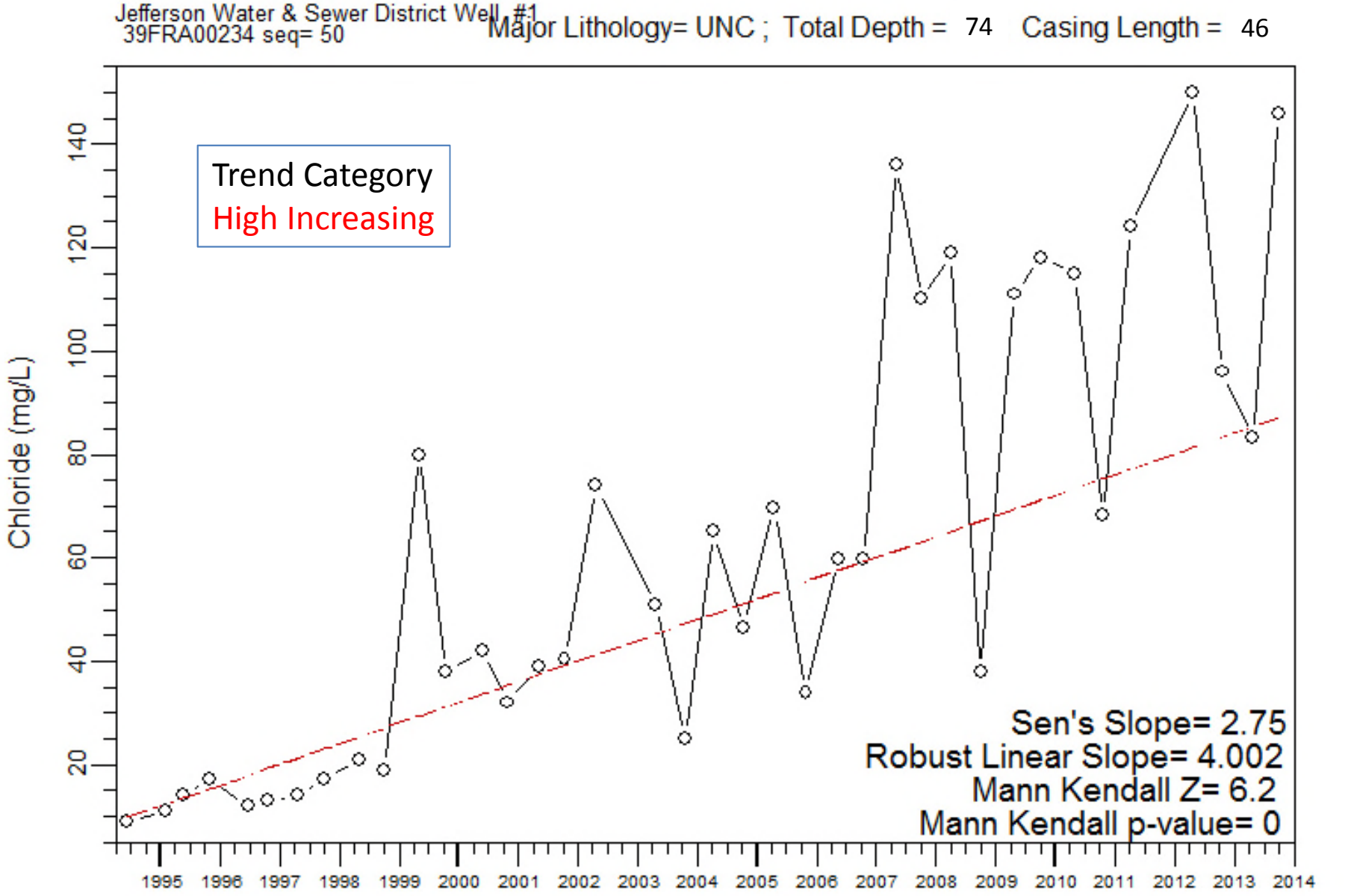
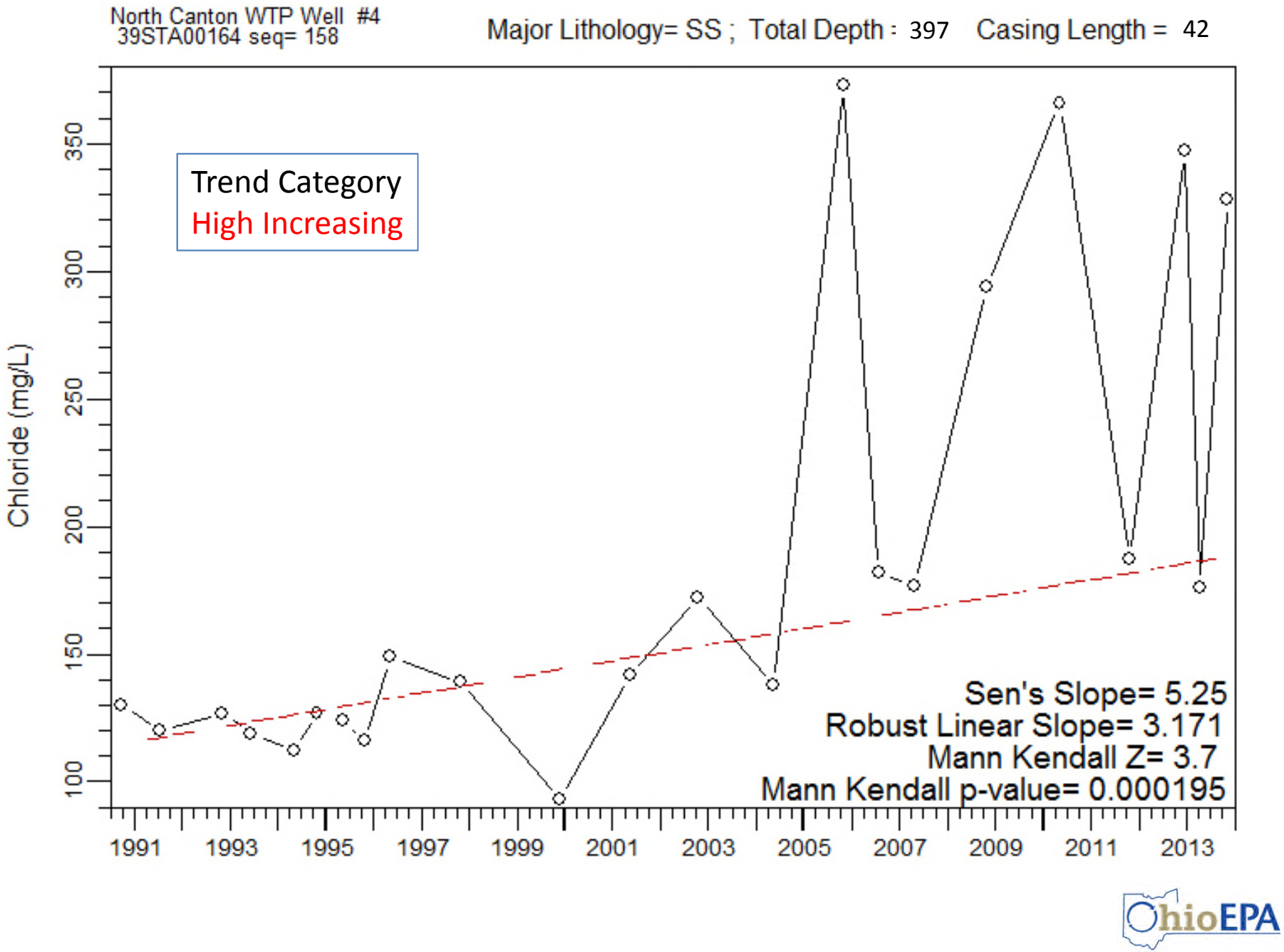
Lancaster Wellfield

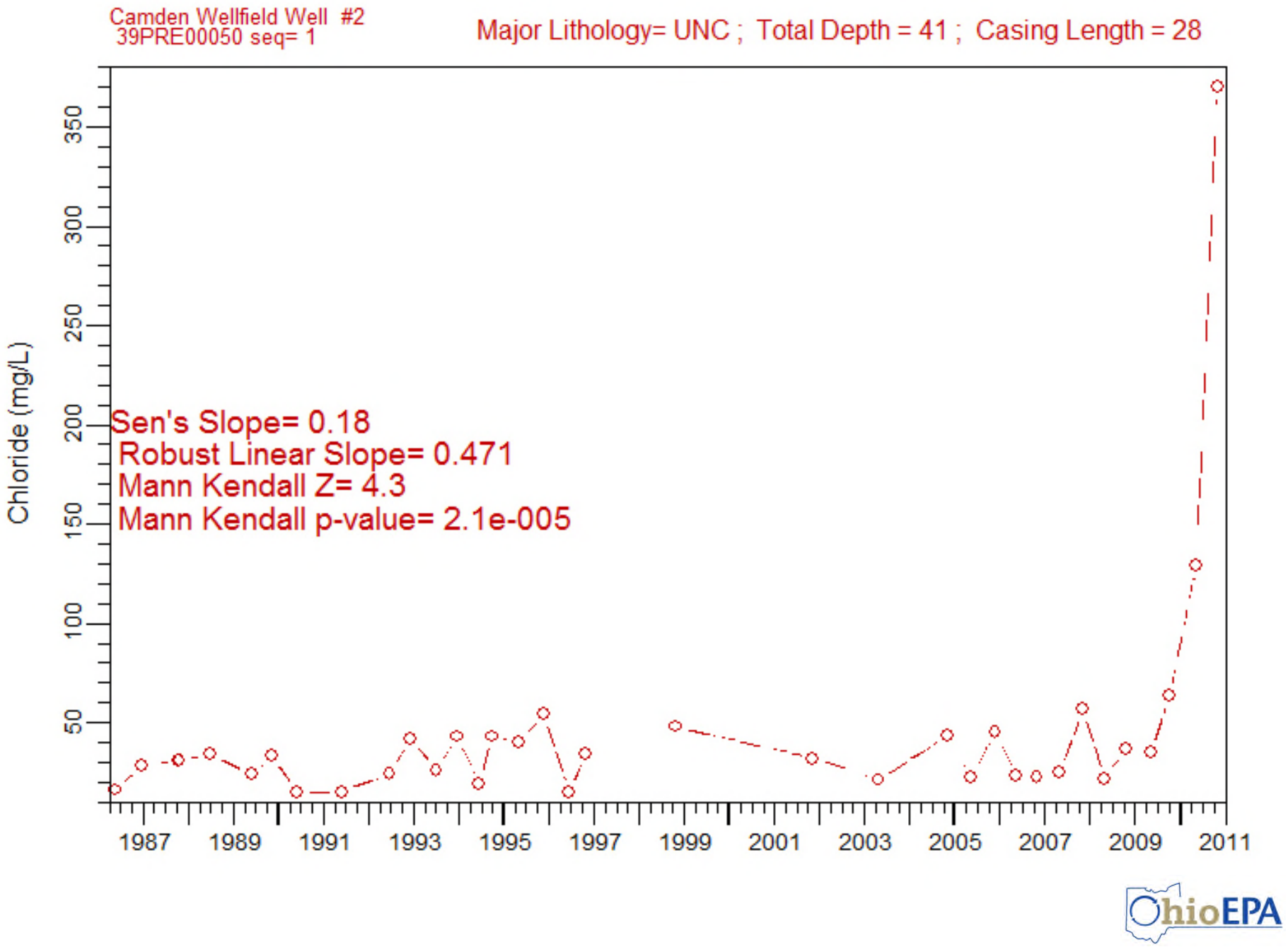



Jefferson Water & Sewer District Well #1
39FRA00234 seq= 50
Major Lithology= UNC ; Total Depth = 74 Casing Length = 46
Trend Category
High Increasing
Chloride (mg/L)
20
40
60
80
100
120
140
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Sen's Slope= 2.75
Robust Linear Slope= 4.002
Mann Kendall Z= 6.2
Mann Kendall p-value= 0

Jefferson W&S District


North Canton WTP Well #4
39STA00164 seq= 158
Major Lithology= SS ; Total Depth = 397 Casing Length = 42
Trend Category
High Increasing
Chloride (mg/L)
100
150
200
250
300
350
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Sen's Slope= 5.25
Robust Linear Slope= 3.171
Mann Kendall Z= 3.7
Mann Kendall p-value= 0.000195

NorthCanton WTP, Well 4


Camden Wellfield Well #2
39PRE00050 seq= 1
Major Lithology= UNC ; Total Depth = 41 ; Casing Length = 28
Chloride (mg/L)
50
100
150
200
250
300
350
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
Sen's Slope= 0.18
Robust Linear Slope= 0.471
Mann Kendall Z= 4.3
Mann Kendall p-value= 2.1e-005
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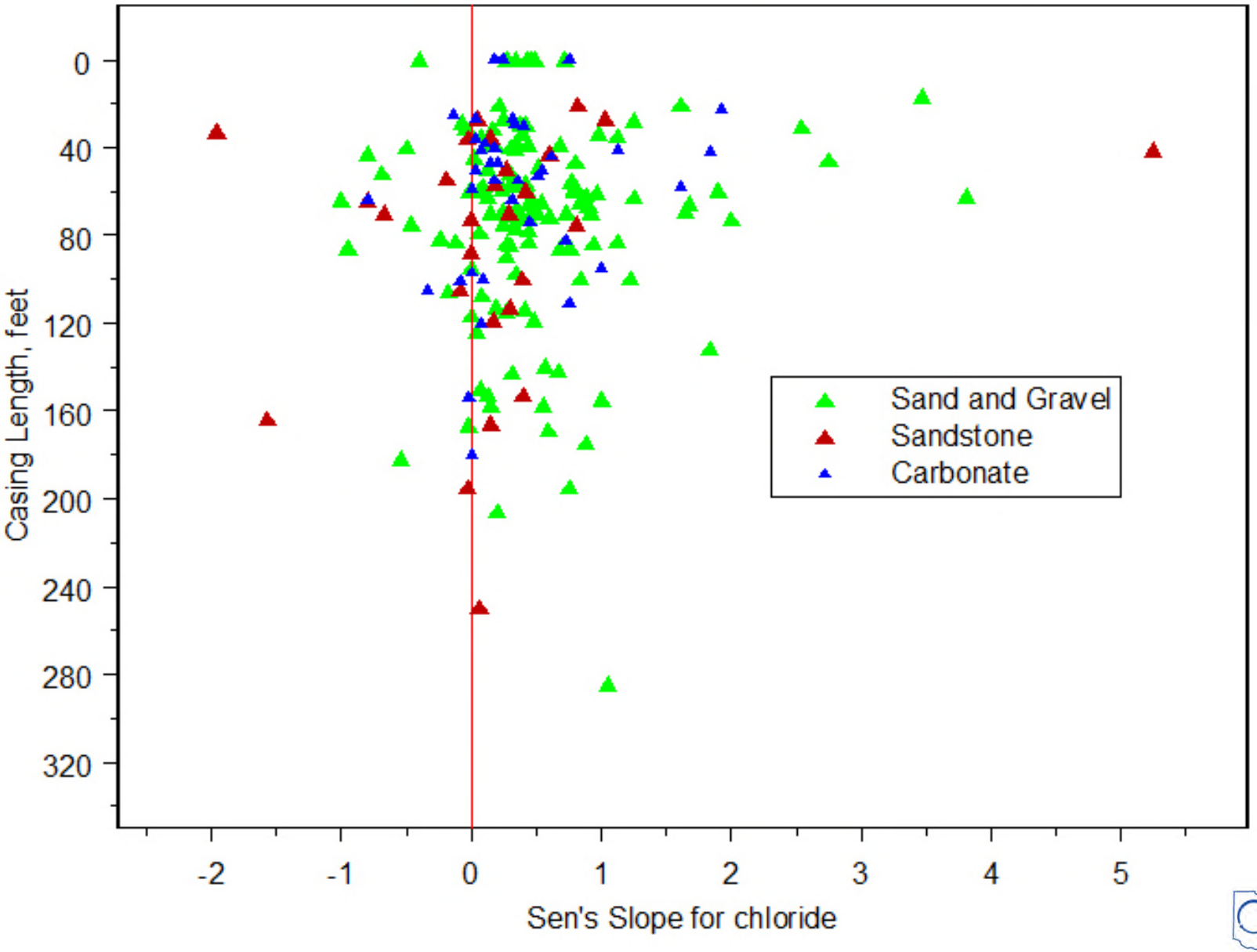
Sen's Slope for Chloride vs Casing Length



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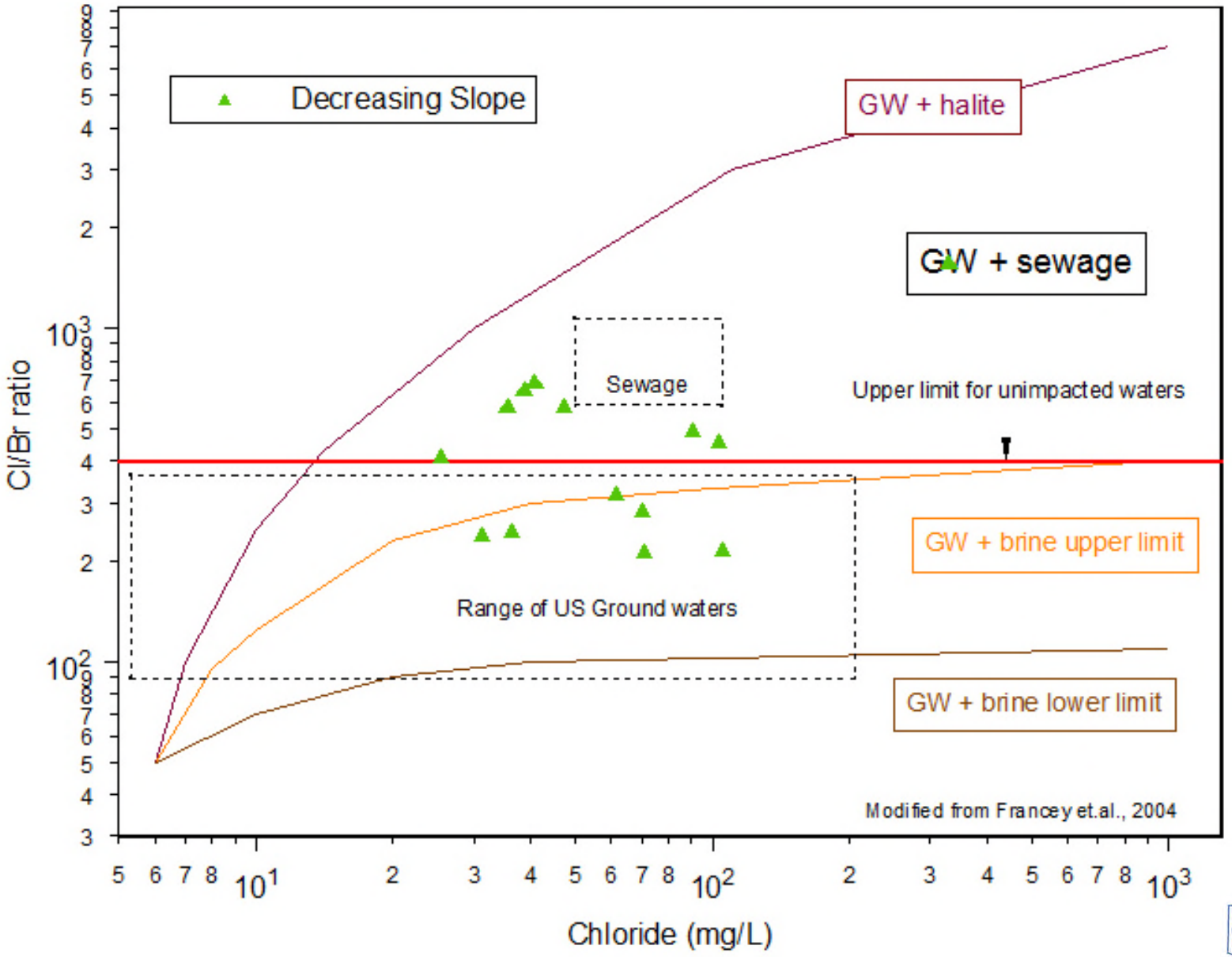
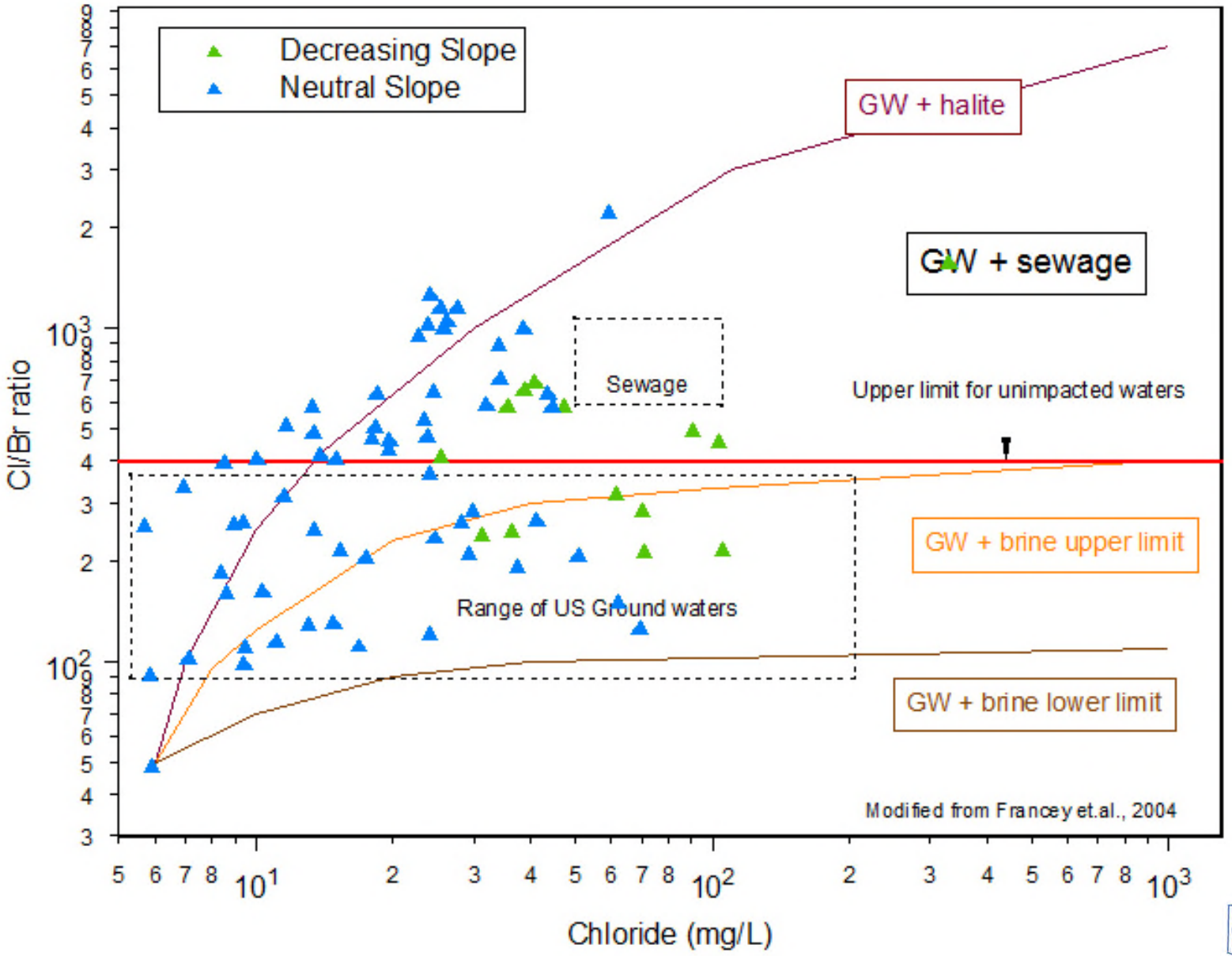
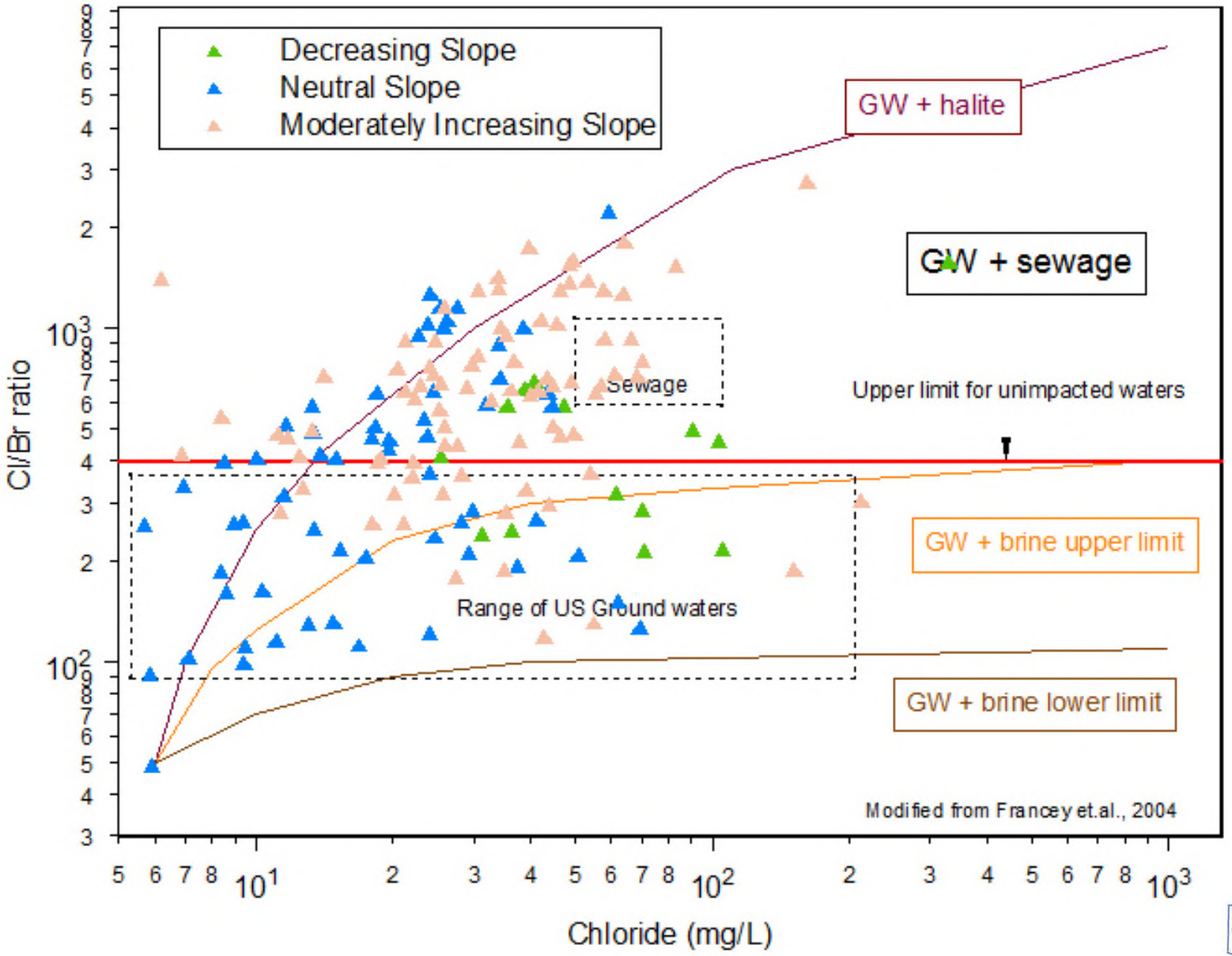
Chloride-Chloride/Bromide Ratio



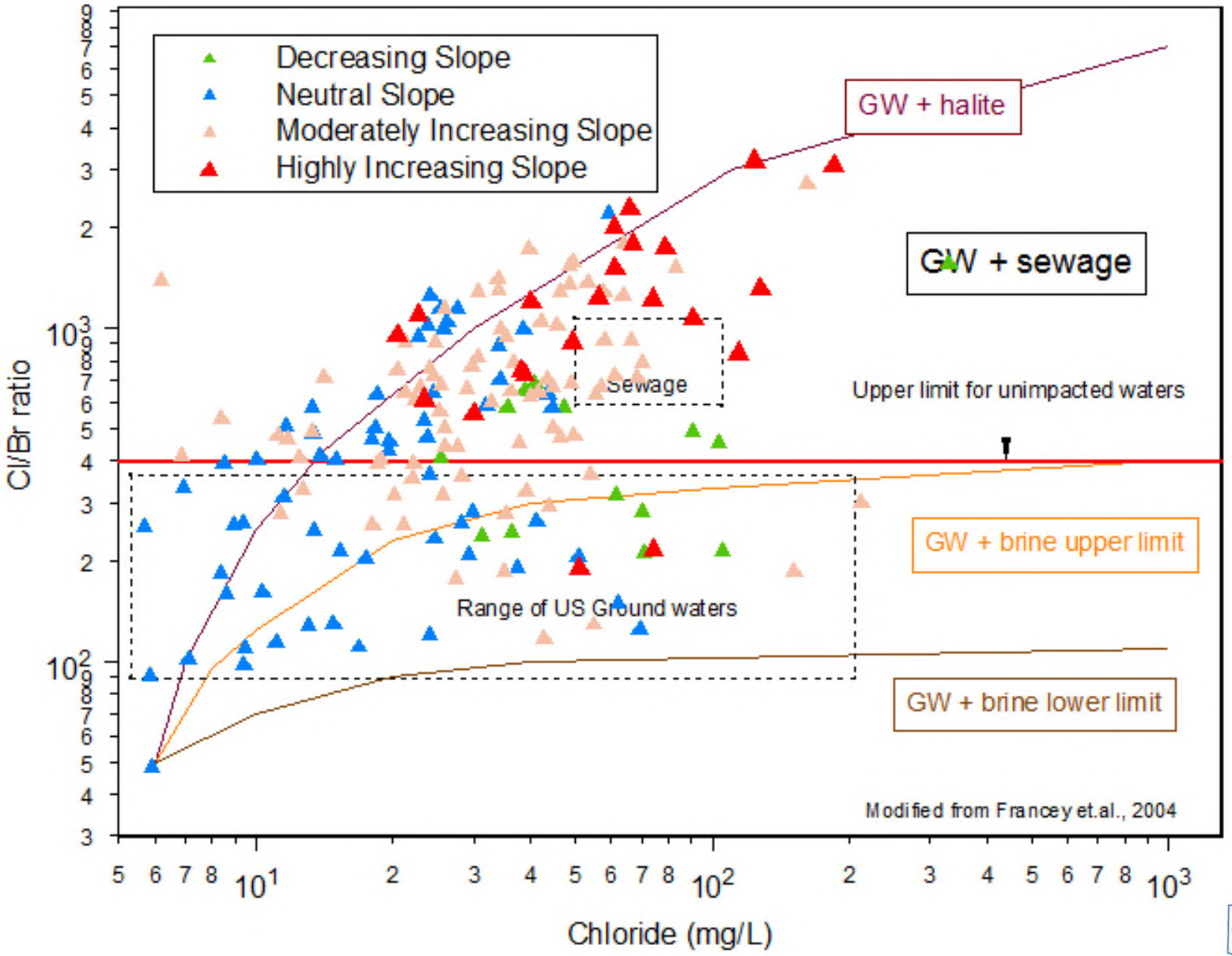
Chloride-Chloride/Bromide Ratio

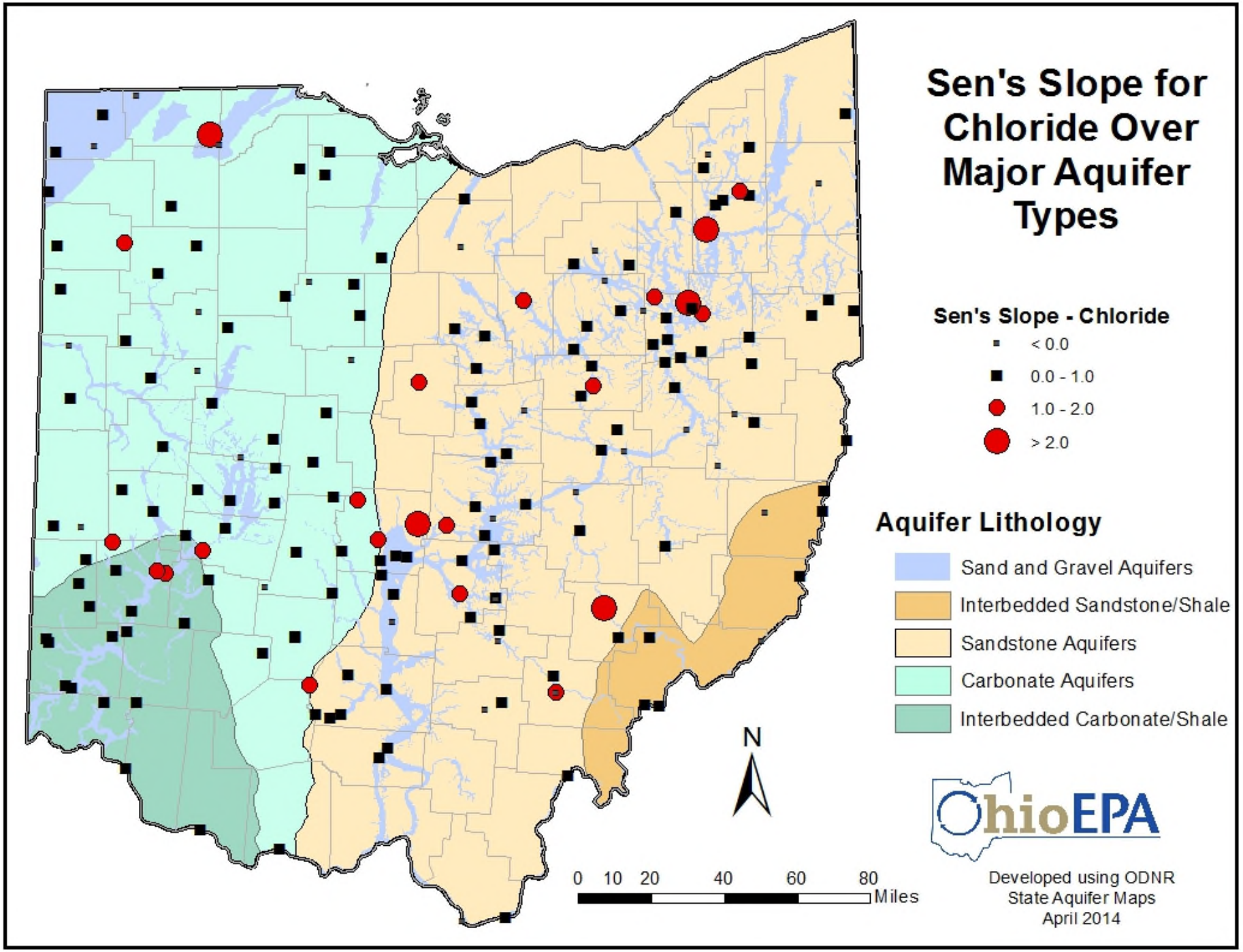


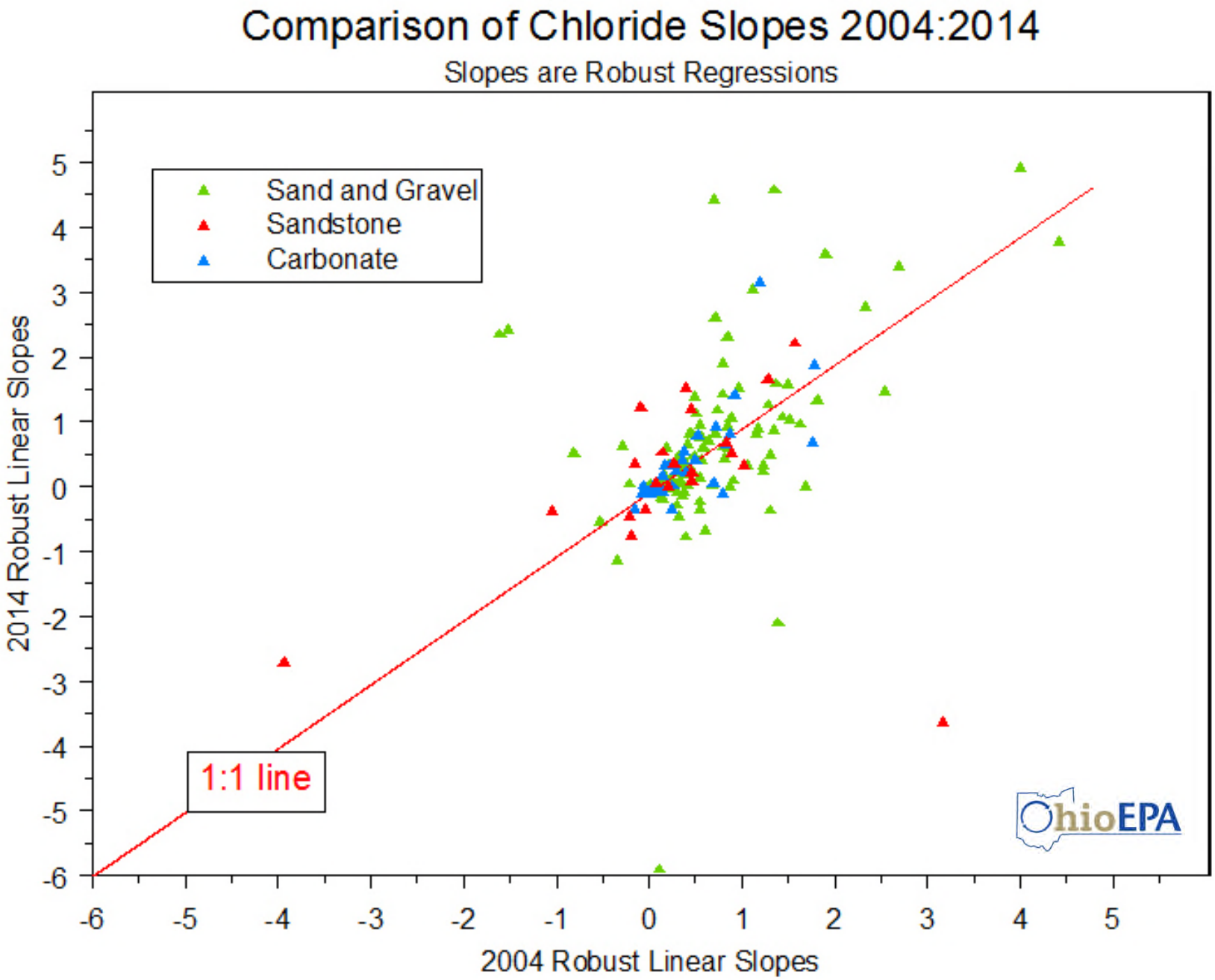
Chloride-Chloride/Bromide Ratio



Chloride-Chloride/Bromide Ratio




Sen's Slope for Chloride Over Major Aquifer Types
Sen's Slope - Chloride
< 0.0
0.0 - 1.0
1.0 - 2.0
> 2.0
Aquifer Lithology
Sand and Gravel Aquifers
Interbedded Sandstone/Shale
Sandstone Aquifers
Carbonate Aquifers
Interbedded Carbonate/Shale
N
0 10 20 40 60 80
Miles
OhioEPA
Developed using ODNR State Aquifer Maps
April 2014


Comparison of Chloride Slopes 2004:2014
Slopes are Robust Regressions
Sand and Gravel
Sandstone
Carbonate
1:1 line
2014 Robust Linear Slopes
2004 Robust Linear Slopes
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
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Conclusions

- Bulk of slopes (68%) between 0 and 1, are stat. significant
- Shallower, unconsolidated wells more sensitive to Cl
  - Casing length
  - Major aquifer
- Comparison 2004:2014 slopes: continued Cl loading:
  - more positive slopes
  - more slopes > 1 mg/L/yr

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Conclusions

- Increasing Cl/Br ratios -> high slopes -> sig. halite contribution
  - Moderate ratios indicate mixed waters, some brine influence
  - Declining slopes mostly unimpacted waters

- Implications of long term loading to PWS wells:
  - Sustainability of water quality over long term in question?
  - Indicates well sensitivity to surface contaminant pathway(s)

- Nitrate trends – preliminary work
  - 50% positive; 50% negative
  - Suggests promising story for wells with significantly decreasing nitrate loading – BMPs, economy

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